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UHV Hollow Cathode Plasma Jet System for Nanostructured Magnetic Films Deposition

F. Fendrych [1*], P. Repa [2], L. Peksa [1,2], J. Poltierova Vejpravova [2],

A. Lancok [1], K. Seemann [3], T.Schafer [4]

[1] *Institute of Physics, Academy of Science CR, Na Slovance 2, CZ-18221 Prague 8,*

[2] *Faculty of Mathematics and Physics, Charles University Prague, V Holesovickach 2, CZ-18000 Prague 8, CZECH REPUBLIC*

[3] *Forschungszentrum Karlsruhe, Institut fuer Materialforschung I, Hermann-von-Helmholtz-Platz 1, D-76344 Egenstein-Leopoldshafen,*

[4] *Leibniz Institute IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, GERMANY*

** Corresponding author e-mail: fendrych@fzu.cz*

Abstract

The specially designed and built UHV bakeable water cooled plasma jet system with DC or RF hollow cathode discharge was successfully used for thin soft ferromagnetic nanocomposite FeCo-AlN films nucleation and growth. Sequentially the layers of pure iron, cobalt, AlN and finally FeCo-AlN magnetic nitride nanocomposite films for GHz applications were deposited.

Keywords: hollow cathode, plasma jet, nanostructured magnetic films

UHV Plasma Jet Apparatus

The hollow-cathode discharge UHV apparatus [1, 2] with high effective pumping speed in the deposition chamber for depositions of nanocomposite magnetic films was originally designed and constructed. The principle is shown in Fig. 1.

Working gas flows through a nozzle made of the material to be deposited. The hollow-cathode discharge (either DC or RF) glowing inside the nozzle (jet) sputters its material and the sputtered particles are carried by the gas stream and deposited on the substrate. The whole device is placed inside a vacuum chamber continually pumped with a high effective pumping speed. UHV apparatus (Fig. 2) bakeable up to 300 °C, ultimate pressure reached before process 3×10^{-8} Pa, fully UHV compatible water cooled plasma jet enabling both DC and RF discharge (0.5 kW power). Water cooled or heated (up to 500 °C) substrate holder, jet-substrate distance is adjustable 1-8 cm. Positions either for two alternating (parallel) jets or for a pair of convergent jets at the chamber.

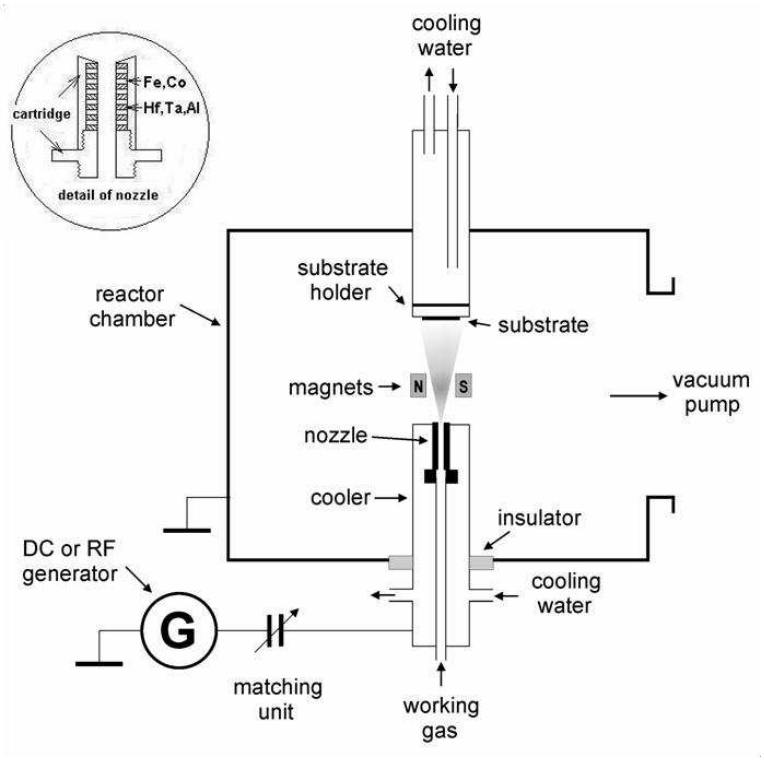

Fig. 1 The principle of hollow-cathode discharge UHV apparatus

Chamber is pumped by cryopump and small turbopump (for pumping at baking-out and when a gas mixture with helium applied as working gas), full pumping speed ≈ 1500 l/s reducible in ratio 1:1000, full requested *p*-*Q* range covered [6].

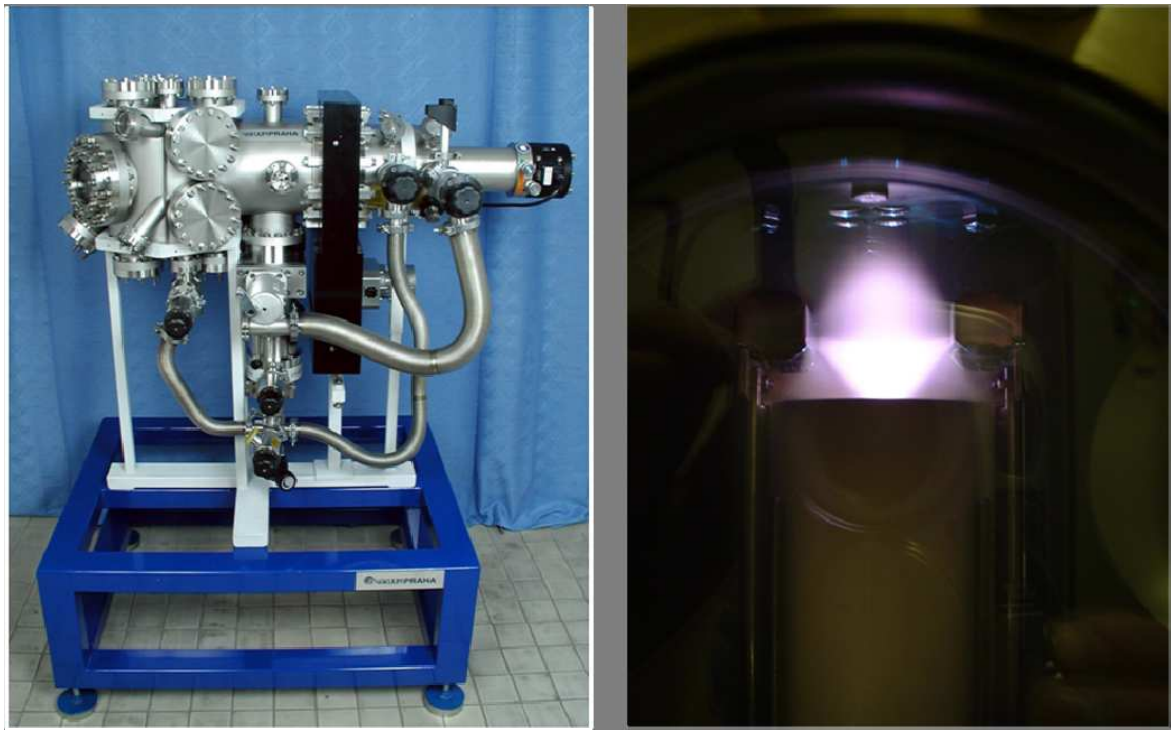

Fig. 2 The constructed UHV plasma jet system at work

Nanostructured Magnetic Film Depositions

The UHV apparatus is successfully used for depositions of special magnetic films based on 3d-metals [1, 2]. These materials consist of elements with very high affinity to oxygen. The first successful experiments with deposition of pure iron Fe, cobalt Co, aluminium Al coatings, preparation of pure dielectric AlN film and stoichiometric soft magnetic mumetal alloy $Ni_{73}Fe_{15}Cu_7Mo_4Mn_1$ films showed that oxygen content in the deposited films is significantly reduced. Addition of oxygen in these films was not higher than 0.02 atomic %. Sequentially the layers of pure iron, cobalt, AlN and finally soft ferromagnetic nitride nanocomposite FeCo-AlN thin films with GHz applications were were deposited. X-ray diffraction spectra and WDX microanalysis revealed that the films consist of nanocrystalline FeCo grains with the size in order of 10 nm (calculated by XRD Scherrer's equation) and of dispersed amorphous AlN nanoclusters. Magnetic domain structure images were obtained by Kerr microscopy in easy axis field, after reducing a hard axis field from saturation and after AC demagnetization in hard axis field. Magnetic domain structure refinement in hard-axis fields and on the edge is typical for magnetically uniaxial thin films. Mössbauer spectra CEMS of the films were decomposed into 5 sextets [7]. Their peaks intensity ratio is 3:4:1:1:4:3. It implies that the FeCo nanocrystallites magnetization is parallel with the film surface.

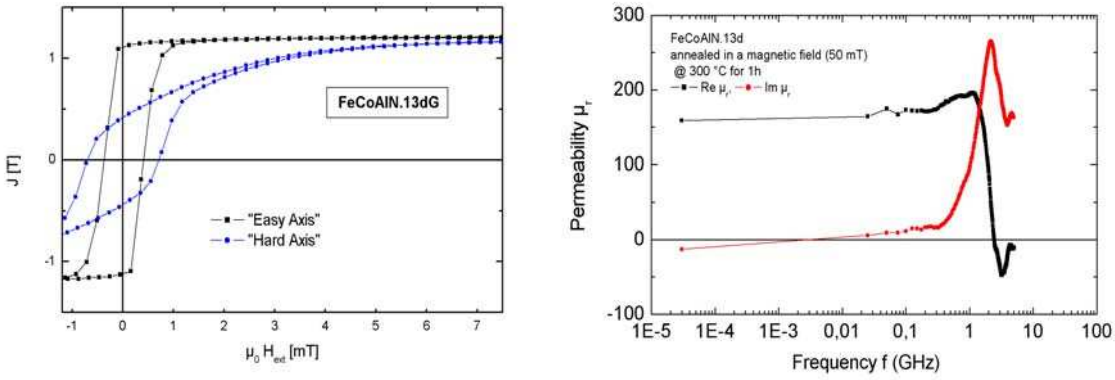

Fig. 3 Hysteresis loops (left) and high frequency permeability (right) of the FeCo-AlN films

Conclusion

Plasma jet technological process was performed by reactive sputtering of combined $Fe_{50}Co_{50}$+Al nozzle in Ar + N_2 working gas mixture flow (total pressure 0.15 Pa, partial N_2 pressure 0.35%) on water-cooled (at 15°C) Si, SiO_2(200nm)/Si and glass substrates. The investigated films have thickness 600 nm and average composition $Fe_{40}Co_{40}Al_{10}N_{10}$. X-ray

diffraction and chemical analysis revealed that the films consist of nanocrystalline FeCo grains with the size of about 10 nm and dispersed amorphous AlN nanoclusters. These materials are magnetically soft with coercivity about 0.4-2.0 mT (Fig. 3, left) [5]. The characteristic frequency at which the natural ferromagnetic resonance occured is about 2.4 GHz (Fig. 3, righ) [6]. The eddy currents in such films are distinctively suppressed in these nanogranular FeCo-AlN composites at their applications in the microinductors for GHz mobile communication devices [3, 4, 5, 6].

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References

[1] F. Fendrych, L. Kraus, O. Chayka, P. Lobotka, I. Vavra, J. Tous, V. Studnicka and Z. Frait, Monatshefte fuer Chemie / Chemical Monthly, Vol. 133 (2002) 773; Special Issue: Nanostructured Materials.

[2] P. Lobotka, I. Vavra, , F. Fendrych, L. Kraus, Journal of Magnetism and Magnetic Materials 240 (2002) 491.

[3] V.Bekker, K.Seemann, and H.Leiste, Journal of Magnetism and Magnetic Materials 270 (2004) 327.

[4] V. Bekker, K. Seemann, H. Leiste, Journal of Magnetism and Magnetic Materials 296 (2006) 37.

[5] O. Zivotsky, F. Fendrych, L. Kraus, K. Postava, O. Chayka, L. Halagacka, J. Pistora, Journal of Magnetism and Magnetic Materials 316 (2007) e858.

[6] F. Fendrych, P. Repa, L. Peksa, T. Gronych, J. Poltierova Vejpravova, A. Lancok, P. Hedbavny, R. Schafer and K.M. Seemann, Journal of Physics: Conference Series 100 (2008) 062008.

[7] A. Lancok, F. Fendrych, M. Miglierini, J. Kohout, and M. Klementova, Journal of Non-Crystalline Solids (2008) in print.